Stock Monitoring Unit in Storage Areas Enable Flexibility, Productivity, and Reliability of Warehousing System

Pornsiri Chatpreecha and Chadaporn Keatmanee

***Abstract*—Dramatic growing in global trading causes inventory levels and their processes in supply chain getting more complex. Therefore, an effective inventory and warehousing management is strongly required in order to reduce errors that may cause by labor resources. One of important duties in warehouse processes is correctly updating stock keeping unit. Since, the errors of this notification may cause delay when the loads have to wait due to out of stock. It will affect to the whole supply chain causing lost in time and cost. In addition, an inaccurate updating may initiate unnecessary ordering which also causes an extra cost. Considering to current inventory management system applying RFID tags, its performance might be affected from metal, liquids or other sources of radio interference. This paper contributes new idea for reducing the errors in warehouse management system. Instead of using on warehouse employees and nor barcode and RFID tags, the machine vision technology is substituted called stock monitoring units dominating in storage areas. The proposed system uses commodity product, which is affordable so it is practical to install stock monitoring units in existing warehousing system requiring small amount of additional cost. Form a number of experiments, the effective of stock monitoring system is evaluated by comparing both time and cost before and after implementation. The experimental outcomes show excellent performance in term of both time and cost.**

***Index Terms*—Monitoring system, stock keeping unit, warehouse and inventory system, machine vision in automated warehouse management system.**

I. Introduction

Various strategies in warehouse management have been applied mostly focusing on cost and time reduction. For example, optimizing sequence of activities flow in warehouse, order-picking method, and cross docking. Another factor that can cause losing of time and cost is delay due to no availability of products to pick or unnecessary ordering due to an inaccurate updating in stock keeping unit. This error may come from different reasons such as warehouse employees do not check stock carefully-human errors, and/or stock keeping units are not up to date (RFID tags or barcode labels are unable to detect-system errors). Therefore, accurate checking of an item availability in its shelf in storage areas is mandatory to implement in order to improve flexibility, productivity, as well as, reliability in warehouse and supply chain management.

We propose an idea for an accurate item monitoring unit updating. Each unit is in charge for each product in its pallet in a warehouse. The item monitoring unit is invented by applying video processing focusing on pattern recognition application. The proposed system requires three cameras for each pallet. For a user interface, the item monitoring unit will show three different statuses of a good availability in a stock including full stock, half stock, as well as stock out. In addition, the system gives a notify when the availability of a good in stock is almost finish (stock out). The application is tested and evaluated in contributed warehouse, which stored frozen food products located in Nakhon Sawan province, Thailand. Based on efficiency of machine vision application, errors from human could be reduced obviously compared with human work. Moreover, the application is developed from community hardware including camera (IP-camera) and budget main board so that it costs small amount of money to implement.

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II. Background

Expanding globalization, development of world economies, growing consumerism, as well as booming of online shopping leads to increase demand for affective logistic system and supply chain, which is more complex. Consequently, there are numerous contributions aimed for expanding an existing system with new logistics facilities [1], [2] especially pointing on warehouse management system. Since, the operations within warehouses have affected tremendously.

A. Warehouse System

Generally, a warehouse consists of a number of parallel aisles with goods stored along sides. With simple storage method (block stacking), small items are often stored in bin shelving and modular storage drawers whereas pallet racks, gravity flow racks, or mobile storage racks is used for larger items. Warehousing system concerns material handling activities that take place within the warehouse, receiving and shipping areas that is the movement of material to, though, and from productive processes [3]. The types of warehouses may distinguish into three types;

- Distribution warehouse: where products come from different suppliers are collected.
- Production warehouse: the place to store raw materials, semi-finished products, and finished products in a production facility.
- Contract warehouse: a facility performs the warehousing operation on behalf of one or more customers.

B. Warehousing Activities

A flow of goods in a warehouse started from products are delivered by trucks and then unloaded at the receiving docks; verify quantity and randomize quality check at the delivered

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loads; prepare the loads for transportation to the storage area (labeling); transport the loads to the storage area. Later on, whenever a product is request it will be retrieved from storage (item picking operation); update Stock Keeping Units (SKU); and finally transport to shipping area.

C. Types of Warehousing System Based on Order Picking Model

Referring to the combination of operating policies and equipment used in an item picking or storage\retrieval environment. Warehousing system can be categorized in to three types [4];

- Manual warehousing systems: the order picker rides a vehicle along pick locations. The order pickers are responsible for the picking of a complete order. The order picker may either sort the orders while traversing the warehouse or the items may be lumped together and sorted afterwards.
- Automated warehousing systems: A carousel or rotary rack is used instead of order picker. It is a computer controlled warehousing system for storage and order picking of small to medium size of goods. The activities are controlled by the carousel including sorting, packaging, and labeling of the retrieved products.
- Automatic warehousing systems: A system performs by replacing a carousel system or rotary rack with robot. Automatic order picking often uses in high speed picking of small or medium products which is non-fragile of uniform size and shape.

D. Warehouse Process

Warehouse process and sub process are sets of actions, which are related to receiving, storage, picking, and shipping of products or material goods. Basically, warehouse process can be implement in various ways (different strategies). The determination of the sequence of the warehouse processes may be considered by different configurations and functional areas of logistic facilities. One of example sequences in the warehousing is shown in Fig. 1 [5]. The activities of each sub process are explained following;

- Receiving includes unloading the material goods, cargo identification, and buffering.
- Put-away includes transport to storage area and placing unit loads in storage location.
- Storage includes stock monitoring.
- Replenishment includes transport to order picking area, transformation of unit loads to from offered in order picking, replenishment to pick location, placing remaining unit loads in storage location, and placing in selected location empty pallets (bins).
- Order picking includes replenishment to pick locations, preparing items for picking, picking items, preparing picked loads for transport, transport of prepared unit loads to selected places in order in picking area, and transport of prepared unit loads to buffer.
- Co-packing includes transport of unit load to co-packing stations, preparing items for co-packing, creation new SKU (Stock Keeping Units), packaging, and transport of prepared unit loads to selected place of buffer.
- Shipping includes buffering, cargo identification and control, and loading.
- Cross-docking includes transport from input buffer to output buffer.

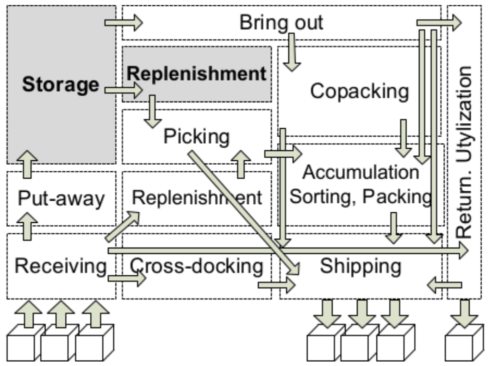

Fig. 1. Main components and the sequence of the warehouse process.

E. Warehouse Management

Typical planning strategies in warehouse are inventory management and storage location assignment that goal for reducing the warehousing costs by applying sophisticate production planning and ordering policies. Several popular strategies are applied in warehouse management explained following;

- Reduction of inventory levels: the strategies may reduce the inventory levels and thereby the operational costs for storage\retrieval and order picking also decrease [6], [7]. For example, cross-docking in which products from incoming trucks are immediately transferred to outgoing trucks.
- Storage allocation and assignment: a popular strategy for reducing the amount of work associated with order picking such as forward-reverse problem (FRP) [8], [9] as well as the observing of busy and idle periods [10].
- Storage location assignment: the problem concerns of incoming stock to storage location. For example, establishment of various storage types or classes [11], [12] sequence of the warehouse activities are analyzed with various methods to find the minimal costs such as decision-making tree [5], [13].

Warehouse management processes and sub processes may be implemented in under various strategies and many different ways. An appropriate strategy may depend on routine warehouse tasks, structure, and scale of orders, handled logistic units, costs of materials, availability of storage space, labor resource, etc. Therefore, technical and organizational factors should be considered for warehouse strategy selection [5]. Appropriate operation of warehouse facilities is a key to enable realization of logistic task at suitable and acceptable by customers' quality level.

F. Current Systems Are Applied in Warehouse Management

Nowadays, devices which are applied in warehouse management system, mostly are barcode labels and RFID tags. Their advantages and disadvantages are discussed as following;

1) Barcode labels

Many warehousing systems utilize barcode label technology which is a simplified warehouse management tools. Its objective is to implement a lean concept for subtracting wastes in time and cost [14]-[17].

Advantages

- Fast for data capturing which can reduce time (paperwork) and chance of errors.
- Reduced labor costs, for instant, the transfer to and from transactions decrease manual effort for writing transactions.
- On-line information benefits timely information.
- A product can be tracked individually in accurate and time.
- Decrease training time, according to, the simple technology which can be easy to be learned by employees.

Disadvantages

- The process for relabeling is costly.
- The labeling at every location can be a time consuming and expensive process.
- The implementation cost and equipment can be significant.
- Environment can affect to label such as hot and humid weather as well as liquid.

2) RFID tags

At the present, warehouse and inventory management technology also employ RFID tags as a main tool for Stock Keeping Units (SKU) which is a possible solution to alleviate the growing in cost and error in warehousing pipeline [15].

Advantages

- No requirement for line of sight in scanning process compared to barcode labels, as well as, employees.
- Reduced labor costs in check-in, picking\packing, and shipment verification.
- Real-time updating and faster scanning using installed RFID readers at each portal.
- A product can be tracked individually in accurate and time.
- Durability is increased compared to barcode labels.

Disadvantages

- Cost of RFID tags is more expensive than barcode labels.
- Upgrading cost of RFID system is another potential for its drawback.
- There are still incompatible standards via tag types, as well as, different industries.
- Environment may affect to label, for example, weather, liquid, and radio sources.

According to the drawbacks of famous current warehouse technology such as barcode label and RFID tags. The tool which does not effect to radio sources, and cost-effective should be applied. The vision-based technology requires few cost for installing (commodity device) and upgrading. It is simple for installation and portable for replacing in different location. The vision-based system is also not being affected from radio source. However, the main disadvantage of the system relies on luminance. Therefore, the constant light environment is mandatory for accurate object detection.

Basically, financial and time cost, availability of storage, labor resources are key ideas for improving effectiveness of warehouse management system. Besides, decreasing time and financial cost, space management and item picking operation in storage, reducing errors caused by human work is one of strategies to enhance performance in warehouse management system. Considering in term of labor resources, it is closely related to materials and information transformation including warehouse employees, transport means, warehouse equipment, tools for information flow management, etc. Differ from those methods discussed in warehouse management subsection, this paper contributes an idea of decreasing errors which may be caused by warehouse employees focusing on the sub processes interconnected with storage which are replenishment and stock keeping units (SKU) in co-packing shown as gray-box in Fig. 1. Delay may occur when loads have to wait due to lack of stock to pick such as if in some areas were lack of the requested material or it will not be available in the expected picking time that will affect to whole supply chain.

Therefore, the strategies to improve effectiveness of warehouse management system should not focus only on order picking model but also SKU, a product and service to identify code for product or store such as bar code that supports for item tracking. Basically, a store uses SKU for determining which item are in stock and which need reordering [14]. The interconnected of sub processes between available space in storage, replenishment (placing remaining unit loads in storage location and placing in selected location empty bin), as well as updating quantity of items in SKU has to be well synchronized. Therefore, solving problems of designing and organizing of synchronizing storage, SKU, and Replenishment in warehouse facilities is the need for improvement in productivity, flexibility and reliability of warehouse management.

We propose sub process called stock monitoring units in storage areas. The sub process's duty is to notify the warehousing system whenever there is no availability of goods at each pallet or shelf. The accurate out of stock notification is required in order to reduce delay that may happen when loads have to wait due to lack of stock to pick. In addition, the proposed idea can be applied in various typological warehouses. The monitoring units are invented by applying machine vision approach. An IP-camera is mounted at each pallet which stores same products (one pallet-one product) with the pattern recognition methods to verify the existing of the product in each shelf.

G. Machine Vison

An ability of computer system to see which employs one or more video cameras along with technology in analog to digital conversion (ADC) and digital signal processing (DSP). The outcome of machine vision is for controlling robot or computer system. There are various industrial applications in machine vision including object recognition, pattern recognition, material inspection, etc. The research's propose is based on pattern recognition to identify the availability of stock in each pallet that utilizes commodity products which are IP-camera and Raspberry pi. Therefore, with the affordable system it is possible to install proposed system in a warehouse as a supplement system by requiring small amount of addition cost.

III. Stock Monitoring Unit

This paper proposes stock monitoring units in order to improve accuracy of stock keeping unit which may cause by human errors. The prototype is applied and evaluation in contributed warehouse in Thailand. The products are frozen foods which are stocked in pallets. Each pallet is monitored by using three cameras fore estimating the amount of goods.

1) Resources

The resources are used in this prototype are categorized in term of place, hardware and software which are described in the next section.

- Warehouse, the prototype is implemented in a warehouse in Nakhon Sawan province Thailand. Although the size of the warehouse is 102 sq.m., the prototype is applied for 26 sq.m. which covers 15 pallets.
- Hardware, one of the goals in this research is to develop stock monitoring units which is not so expensive for implementation. Therefore, commodity devices are used including IP camera, small and budget main board, as well as wireless router. The overall implemented devices are shown in figure 2. For one rack, stock monitoring unit is compost of three cameras to ensure that all goods are captured.

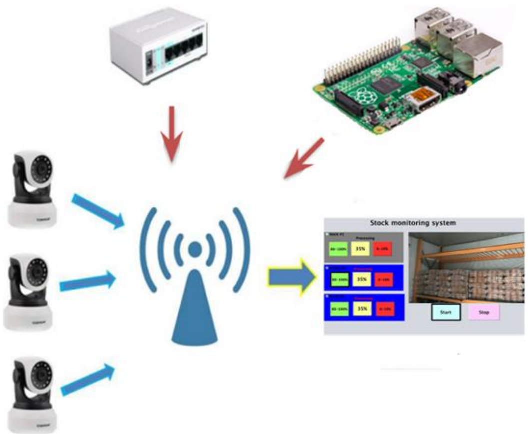

Fig. 2. The components of a stock monitoring system.

2) Software

The use case of stock monitoring unit is shown in Fig. 4, users are able to set parameters (threshold value for notification statuses), as well as start and stop stock monitoring units. Whereas, the stock monitoring units work for video processing and estimate amount of product availability in the pallets. The flow of all processes is shown in Fig. 3. The Harr cascade method is utilized for object detection has been initially proposed by Paul Viola [15] and improved by Rainer Lien hart [16] The processes to implement the goods in warehouse which mostly have rectangle shapes are described as following;

- A classifier named a cascade that works with Harr-like features is trained with a hundred samples view of a shape of a frozen food container called positive examples, that are scaled to the same size, and negative examples arbitrary images of the same size.
- After a classifier is trained, it can be applied to a region of interest in an input image. The classifier is designed so that it can be easily "resized" in order to be able to find the objects of interest at different sizes, which is more efficient than resizing the image itself. So, to find an object of an unknown size in the image the scan procedure should be done several times at different scales.

IV. Results and Discussion

The monitoring system is able to estimate amount of the good in each pallet approximately by showing three difference statuses as shown in Fig. 5. Therefore, staffs in the warehouse are notified the approximately goods availability in each pallet so they can update stock keeping units more accurately. Moreover, the error of out of stock and unnecessary ordering may not happen.

The stock monitoring unit is evaluated in the warehouse covering 26 sq.m. The system is measured its performance in six months from January to June. The period of system evaluation is shown in Table I and Table II. In each day the performance of the system is evaluate by a program with at least 40 minutes and at most 90 minutes using two mode of video processing including sampling and real time.

According to disadvantage of video processing techniques, the stock monitoring system is suffered from inappropriate luminous intensity. From Table III and Table IV show effect of the light to the system according to time period. The most suitable of luminous intensity is in period 3 which mostly closes to an ideal value, 526.

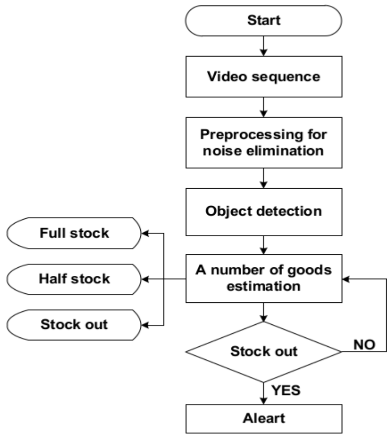

Fig. 3. The flow of the stock monitoring system.

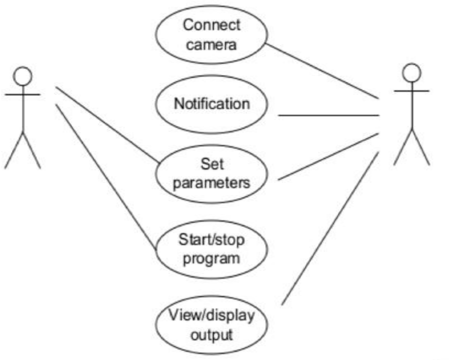

Fig. 4. The use case diagram of monitoring system.

The errors of stock monitoring system is evaluated according to month (six months from January to June) shown in Table V. Because the prototype is measured and improved in every month, the errors of the system is reduced gradually every month.

TABLE I: TIME PERIOD AND TIME RANG FOR STOCK MONITORING SYSTEM UNIT EVALUATION

Period	Time Range	Time(min)
1	10.00-12.00	40
2	12.30-14.30	75
3	16.00-18.00	60
4	18.30-20.30	90
5	21.00-22.00	45

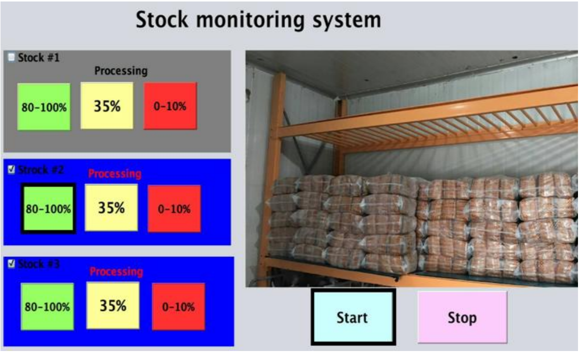

Fig. 5. The example of stock monitoring unit interface.

TABLE II: METHOD FOR VIDEO PROCESSING FOR STOCK MONITORING SYSTEM UNIT EVALUATION

Period	Time Range	Mode
1	10.00-12.00	Sampling
2	12.30-14.30	Real time
3	16.00-18.00	Real time
4	18.30-20.30	Real time
5	21.00-22.00	Real time

TABLE III: LUMINOUS INTENSITY EVALUATION

Period	Time Range	Luminous intensity
1	10.00-12.00	623
2	12.30-14.30	685
3	16.00-18.00	544
4	18.30-20.30	490
5	21.00-22.00	347

TABLE IV: LUMINOUS INTENSITY EVALUATION

Accuracy (%)	Accuracy/period (%)	Periods
0	5.5	1,2,5
20	7.25	1,2
40	10.5	4,5
60	18.25	3,4,5
80	30.25	3,4,5
100	28.25	4,5

Table IV illustrates the stock monitoring system can support for effective ordering due to inaccurate estimation of good availability in each pallet. Hence, the number of ordered items are reduced dramatically that affects to cost reduction as well for unnecessary ordering.

TABLE V: AN AVERAGE AND STANDARD DEVIATION OF THE SYSTEM ERROR OCCURRING FROM JANUARY TO JUNE

Month	Error	
	Avgs.	SD.
January	15.00	2.24
February	10.00	1.83
March	5.00	1.67
April	5.00	1.67
May	5.00	1.55
June	5.00	1.43

Table V and Table VI show the dramatic reduction of put-away process after applying stock monitoring system because the system can notify which pallet is needed for replenishment. Therefore, it can reduce an unnecessary put-away process efficiently. Besides time and cost-effective evaluation, we also test the effectiveness of our proposed method for eliminating errors in order process within 180 days as shown in Table VII and Table VIII. The results show dramatically decreasing human-error after applying stock monitoring units.

TABLE VI: THE PUT-AWAY PROCESS EVALUATION BEFORE AND AFTER USING STOCK MONITORING SYSTEM

Month	No. of order items(tons)	No. of Distributed item.			
		Before		After	
		tons	%	tons	%
January	350	23.5	93.29%	13	55.32%
February	480	54	84.57%	24	44.44%
March	382	26	92.57%	9	34.62%
April	358	48	86.29%	21	43.75%
May	450	37	89.43%	17	45.95%
June	559	49	86.00%	26	53.06%

TABLE VII: A NUMBER OF ORDERING FOR OBSERVED ITEMS IN 180 DAYS BEFORE APPLYING STOCK MONITORING UNITS

Period	Time Range	Before Process Ordering		
		Put-away (180days)	Replenishment (180days)	Stocking (180days)
1	07.00-10.00	360	360	360
2	14.00-16.00	360	720	540
3	18.00-20.00	360	540	720
Summary		1080	1620	1620
Total		**4320times /180 days**		

TABLE VIII: A NUMBER OF ORDERING FOR OBSERVED ITEMS IN 180 DAYS AFTER APPLYING STOCK MONITORING UNITS

Period	Time Range	After Process Ordering		
		Put-away (180days)	Replenishment (180days)	Stocking (180days)
1	07.00-10.00	180	180	180
2	14.00-16.00	180	360	180
3	18.00-20.00	180	360	180
Summary		540	900	540
Total		**1980 times/180 days**		

V. CONCLUSION

This paper proposes an idea for reducing error in stock keeping unit which are caused by human that is a stock monitoring unit. The unit is able to capture goods in each pallet by using three IP cameras for a pallet and then applying project detection method for estimating amount of good in the pallet. The system can notify users for three-status notification, hence a warehouse staff can be aware from the system for appropriate order. The prototype is evaluated in real warehouse in Thailand covering 26 sq.m. by comparing before and after collected data for put-away process and amount of order. From the evaluation, the system is able to reduce human errors dramatically. However, according to the video processing technique the system performance is dropped when there is improper luminous intensity. The future work would be improved the object detection method to be tolerate to the difference of light and increase areas of evaluation which might cover the whole warehouse (102 sq.m.)

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